

09/720329.

PCT/NO00/00127

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE
in its capacity as elected Office

Date of mailing (day/month/year) 04 April 2001 (04.04.01)	
International application No. PCT/NO00/00127	Applicant's or agent's file reference Opti42PCT
International filing date (day/month/year) 14 April 2000 (14.04.00)	Priority date (day/month/year) 22 April 1999 (22.04.99)
Applicant ROMAN, Lucimara, Stolz et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
20 November 2000 (20.11.00)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Charlotte ENGER
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

2818

From the INTERNATIONAL BUREAU

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

To:

LEISTAD, Geirr, I.
Thin Film Electronics ASA
P.O. Box 1872 Vika
N-0124 Oslo
NORVÈGE

Date of mailing (day/month/year) 10 April 2001 (10.04.01)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference Opti42PCT	
International application No. PCT/NO00/00127	International filing date (day/month/year) 14 April 2000 (14.04.00)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address

LEISTAD, Geirr, I.
Thin Film Electronics ASA
P.O. Box 1872 Vika
N-0124 Oslo
Norway

State of Nationality

State of Residence

Telephone No.

+47 23 23 84 40

Facsimile No.

+47 23 23 84 40

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address

State of Nationality

State of Residence

Telephone No.

+47 23 01 12 40

Facsimile No.

+47 23 01 12 41

Teleprinter No.

3. Further observations, if necessary:

Please note new telephone and new fax numbers of the agent.

4. A copy of this notification has been sent to:

☒ the receiving Office ☐ the designated Offices concerned
☐ the International Searching Authority ☒ the elected Offices concerned
☒ the International Preliminary Examining Authority ☐ other:
The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

F. Baechler

Telephone No.: (41-22) 338.83.38

KOP1 till orientering

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

PCT/NO 00 / 00127

International Application No. 09 / 720329

2000 -04- 14 (14.04.00)

International Filing Date



PATENTSTYRET

Eigent för det industriella rättssystemet

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference

(if desired) (12 characters maximum)

Opti42PCT

Box No. I TITLE OF INVENTION

A method in the fabrication of organic thin-film semiconducting devices

Box No. II APPLICANT

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

THIN FILM ELECTRONICS ASA
P.O.Box 1872 Vika
N-0124 Oslo
Norway

☐ This person is also inventor.

Telephone No.

+47 23238440

Facsimile No.

+47 23238441

Teleprinter No.

State (that is, country) of nationality:

NO

State (that is, country) of residence:

NO

This person is applicant for the purposes of:



all designated States



all designated States except the United States of America



the United States of America only



the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

ROMAN, Lucimara Stolz
Mårdtorpsgatan 29
S-58432 Linköping
Sweden

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

BR

State (that is, country) of residence:

SE

This person is applicant for the purposes of:



all designated States



all designated States except the United States of America



the United States of America only



the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:



agent



common representative

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

LEISTAD, Geirr I. of
THIN FILM ELECTRONICS ASA
P.O.Box 1872 Vika
N-0124 Oslo
Norway

Telephone No.

Facsimile No.

+47 23 23 84 40

Teleprinter No.

+47 23 23 84 41

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

CONFIRMATION COPY

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

INGANÄS, Olle
Wernersgatan 13
S-58235 Linköping
Sweden

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

SE

State (that is, country) of residence:

SE

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☒ the United States of America only

☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

HAGEL, Olle
Lektorsgatan 3
S-58235 Linköping
Sweden

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

SE

State (that is, country) of residence:

SE

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☒ the United States of America only

☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

BERGGREN, Magnus
Bergsbadsvägen 14
S-59077 Vreta Kloster
Sweden

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

SE

State (that is, country) of residence:

SE

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☒ the United States of America only

☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

GUSTAFSSON, Göran
Trumslagaregatan 33
S-58216 Linköping
Sweden

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

SE

State (that is, country) of residence:

SE

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☒ the United States of America only

☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on another continuation sheet.

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

CARLSSON, Johan
Ekholmsvägen 219
S-58929 Linköping
Sweden

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

SE

State (that is, country) of residence:

SE

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (that is, country) of nationality:

State (that is, country) of residence:

This person is applicant for the purposes of:

☐ all designated States

☐ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) (mark the applicable check-boxes; at least one must be marked):

Regional Patent

- ☒ AP ARIPO Patent: GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, TZ United Republic of Tanzania, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☒ EA Eurasian Patent: AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ EP European Patent: AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☒ OA OAPI Patent: BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT (if other kind of protection or treatment desired, specify on dotted line)

National Patent (if other kind of protection or treatment desired, specify on dotted line):

- | | |
|--|--|
| <input checked="" type="checkbox"/> AE United Arab Emirates | <input checked="" type="checkbox"/> LR Liberia |
| <input checked="" type="checkbox"/> AL Albania | <input checked="" type="checkbox"/> LS Lesotho |
| <input checked="" type="checkbox"/> AM Armenia | <input checked="" type="checkbox"/> LT Lithuania |
| <input checked="" type="checkbox"/> AT Austria | <input checked="" type="checkbox"/> LU Luxembourg |
| <input checked="" type="checkbox"/> AU Australia | <input checked="" type="checkbox"/> LV Latvia |
| <input checked="" type="checkbox"/> AZ Azerbaijan | <input checked="" type="checkbox"/> MA Morocco |
| <input checked="" type="checkbox"/> BA Bosnia and Herzegovina | <input checked="" type="checkbox"/> MD Republic of Moldova |
| <input checked="" type="checkbox"/> BB Barbados | <input checked="" type="checkbox"/> MG Madagascar |
| <input checked="" type="checkbox"/> BG Bulgaria | <input checked="" type="checkbox"/> MK The former Yugoslav Republic of Macedonia |
| <input checked="" type="checkbox"/> BR Brazil | <input checked="" type="checkbox"/> MN Mongolia |
| <input checked="" type="checkbox"/> BY Belarus | <input checked="" type="checkbox"/> MW Malawi |
| <input checked="" type="checkbox"/> CA Canada | <input checked="" type="checkbox"/> MX Mexico |
| <input checked="" type="checkbox"/> CH and LI Switzerland and Liechtenstein | <input checked="" type="checkbox"/> NO Norway |
| <input checked="" type="checkbox"/> CN China | <input checked="" type="checkbox"/> NZ New Zealand |
| <input checked="" type="checkbox"/> CR Costa Rica | <input checked="" type="checkbox"/> PL Poland |
| <input checked="" type="checkbox"/> CU Cuba | <input checked="" type="checkbox"/> PT Portugal |
| <input checked="" type="checkbox"/> CZ Czech Republic | <input checked="" type="checkbox"/> RO Romania |
| <input checked="" type="checkbox"/> DE Germany | <input checked="" type="checkbox"/> RU Russian Federation |
| <input checked="" type="checkbox"/> DK Denmark | <input checked="" type="checkbox"/> SD Sudan |
| <input checked="" type="checkbox"/> DM Dominica | <input checked="" type="checkbox"/> SE Sweden |
| <input checked="" type="checkbox"/> EE Estonia | <input checked="" type="checkbox"/> SG Singapore |
| <input checked="" type="checkbox"/> ES Spain | <input checked="" type="checkbox"/> SI Slovenia |
| <input checked="" type="checkbox"/> FI Finland | <input checked="" type="checkbox"/> SK Slovakia |
| <input checked="" type="checkbox"/> GB United Kingdom | <input checked="" type="checkbox"/> SL Sierra Leone |
| <input checked="" type="checkbox"/> GD Grenada | <input checked="" type="checkbox"/> TJ Tajikistan |
| <input checked="" type="checkbox"/> GE Georgia | <input checked="" type="checkbox"/> TM Turkmenistan |
| <input checked="" type="checkbox"/> GH Ghana | <input checked="" type="checkbox"/> TR Turkey |
| <input type="checkbox"/> GM Gambia | <input checked="" type="checkbox"/> TT Trinidad and Tobago |
| <input checked="" type="checkbox"/> HR Croatia | <input checked="" type="checkbox"/> TZ United Republic of Tanzania |
| <input checked="" type="checkbox"/> HU Hungary | <input checked="" type="checkbox"/> UA Ukraine |
| <input checked="" type="checkbox"/> ID Indonesia | <input checked="" type="checkbox"/> UG Uganda |
| <input checked="" type="checkbox"/> IL Israel | <input checked="" type="checkbox"/> US United States of America |
| <input checked="" type="checkbox"/> IN India | <input checked="" type="checkbox"/> UZ Uzbekistan |
| <input checked="" type="checkbox"/> IS Iceland | <input checked="" type="checkbox"/> VN Viet Nam |
| <input checked="" type="checkbox"/> JP Japan | <input checked="" type="checkbox"/> YU Yugoslavia |
| <input checked="" type="checkbox"/> KE Kenya | <input checked="" type="checkbox"/> ZA South Africa |
| <input checked="" type="checkbox"/> KG Kyrgyzstan | <input checked="" type="checkbox"/> ZW Zimbabwe |
| <input checked="" type="checkbox"/> KP Democratic People's Republic of Korea | Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet: |
| <input checked="" type="checkbox"/> KR Republic of Korea | <input checked="" type="checkbox"/> DZ Algeria |
| <input checked="" type="checkbox"/> KZ Kazakhstan | <input type="checkbox"/> |
| <input checked="" type="checkbox"/> LC Saint Lucia | |
| <input checked="" type="checkbox"/> LK Sri Lanka | |

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)

Box No. VI PRIORITY CLAIM

☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is:		
		national application: country	regional application:* regional Office	international application: receiving Office
item (1) 22 April 1999 (22.04.99)	1999 1916	NO		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) (only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office) identified above as item(s): (1)

* Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA)
(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):

Request to use results of earlier search; reference to that search (if an earlier search has been carried out by or requested from the International Searching Authority):

ISA / SE

Date (day/month/year)

Number

Country (or regional Office)

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following number of sheets:

request : 5
description (excluding
sequence listing part) : 15
claims : 3
abstract : 1
drawings : 8
sequence listing part
of description : _____

Total number of sheets : 32

This international application is accompanied by the item(s) marked below:

- ☒ fee calculation sheet
- ☐ separate signed power of attorney
- ☐ copy of general power of attorney; reference number, if any:
- ☐ statement explaining lack of signature
- ☐ priority document(s) identified in Box No. VI as item(s):
- ☐ translation of international application into (language):
- ☐ separate indications concerning deposited microorganism or other biological material
- ☐ nucleotide and/or amino acid sequence listing in computer readable form
- ☒ other (specify): Copy of Search Report in NO19991916

Figure of the drawings which should accompany the abstract:

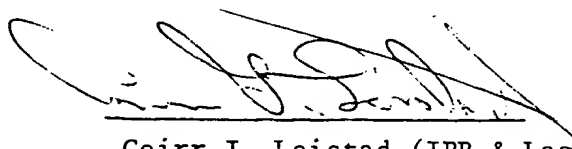
Language of filing of the international application:

Norwegian

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

THIN FILM ELECTRONICS ASA



Geirr I. Leistad (IPR & Legal Department Manager)

For receiving Office use only

1. Date of actual receipt of the purported international application:

2000 -04- 14

(14.04.00)

2. Drawings:

☒ received:

☐ not received:

3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:

4. Date of timely receipt of the required corrections under PCT Article 11(2):

5. International Searching Authority (if two or more are competent):

ISA / SE

6. ☐

Transmittal of search copy delayed until search fee is paid.

Date of receipt of the record copy by the International Bureau:

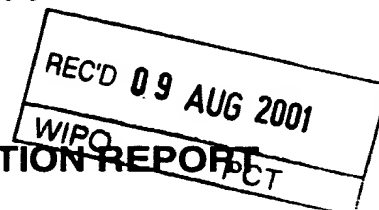
For International Bureau use only


PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)



Applicant's or agent's file reference Opti42PCT		FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/NO00/00127	International filing date (day/month/year) 14/04/2000	Priority date (day/month/year) 22/04/1999	
International Patent Classification (IPC) or national classification and IPC H01L27/01			
Applicant THIN FILM ELECTRONICS ASA et al.			
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 8 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of 27 sheets.</p>			
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"> I <input checked="" type="checkbox"/> Basis of the report II <input type="checkbox"/> Priority III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability IV <input checked="" type="checkbox"/> Lack of unity of invention V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement VI <input type="checkbox"/> Certain documents cited VII <input checked="" type="checkbox"/> Certain defects in the international application VIII <input checked="" type="checkbox"/> Certain observations on the international application 			
Date of submission of the demand 20/11/2000		Date of completion of this report 07.08.2001	
Name and mailing address of the international preliminary examining authority:  European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465		Authorized officer Bernabé Prieto, A Telephone No. +49 89 2399 2224	



INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NO00/00127

I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

Description, pages:

1-16 with telefax of 22/06/2001

Claims, No.:

1-16 with telefax of 22/06/2001

Drawings, sheets:

1/8-8/8 with telefax of 22/06/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NO00/00127

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
☐ paid additional fees.
☐ paid additional fees under protest.
☐ neither restricted nor paid additional fees.

2. ☒ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

- ☐ complied with.
☒ not complied with for the following reasons:
see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- ☒ all parts.
☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	3-16
	No:	Claims	1-2
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-16

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/NO00/00127

Industrial applicability (IA) Yes: Claims 1-16
 No: Claims

2. Citations and explanations
 see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/NO00/00127

The comments relate to items I to VIII of the cover sheet, where the corresponding cases have been crossed.

1 Reference is made to the following documents:

D1: WO-A-98/53510

D2: EP-A-0 901 176

D3: EP-A-0 716 459

2 The amendments filed with the fax dated the 22.06.2001 introduce subject-matter which extends beyond the disclosure of the international application as filed, contrary to Article 34(2)(b) PCT. The amendments concerned are the following:

2.1 Claim 1 filed with the fax dated the 22.06.2001 discloses a method in the fabrication of an electrode means comprising two layers, whereas in the application as originally filed (cf. claim 1 and originally filed page 3) the electrode means is disclosed only as a part of an organic thin film semiconducting device, i. e. only in conjunction with the rest of the features which form, together with the electrode, the organic thin film semiconducting device (substrate, organic semiconducting material and cathode layers). Therefore, the subject-matter of present claim 1 extends beyond the disclosure of the international application as filed, contrary to the requirements set forth in Article 34(2)(b) PCT.

2.2 Claim 2 filed with the fax dated the 22.06.2001 discloses:

a second/fourth layer "over" (i. e. other layers may be therebetween) the first/third layer", whereas in the application as filed the second/fourth layer is "on" the first/third layer;

the fourth layer is not limited to a metal, but is of any material;

the third and fourth layer are "provided" (e. g. grown, deposited, bonded), whereas in the application as filed they are only "deposited";

the unclear expressions (Article 6 PCT) "in the form of" and "being selected as" does not disclose that the layers to which this expression refers are made "of" the materials referred to by this expression, thus said layers being of any material;

the work function of the (material of the?) second layer is also "equal to" that of the (material of the?) first layer, not only "greater than" it;

the second layer now only "partly covers" the first one, whereas in the originally filed claim 1 the second layer "mainly covers the first layer";

- 2.3 The total or partial deletion of the text in the figures 2c, 3A and 3B filed with the fax of 22.06.2001, broadens the extent of subject-matter beyond that of the originally filed application, the device/measurements therein disclosed not corresponding (thus being limited to) any more to the materials and devices disclosed in the text of the originally filed and corresponding figures.
- 2.4 The fax of 22.06.2001 introduces new figures 3c-3f for which there is no basis in the application as originally filed.
- 2.5 The description pages 1-16 filed with the fax dated the 22.06.2001 introduce subject-matter which extends beyond the disclosure of the international application as filed, contrary to Article 34(2)(b) PCT.
- 3 The present application does not meet the requirements of Article 6 PCT, because claims 1-16 are not clear.
- 3.1 The existence of several possible combinations of features derived from the wording of either of claims 1 or 2, renders the claims not concise. Moreover, a lack of clarity of the claims arises, since it results difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection. Hence, claims 1, 2 and 3-16, as dependent on claims 1 and 2, do not meet the requirements of Article 6 PCT.
- 3.2 The formulation in claim 2 "whereby the work function .. polymer" is vague and

unclear and leaves the reader in doubt as to the meaning of the technical features to which it refers, thereby rendering the definition of the subject-matter of said claims unclear (Article 6 PCT).

- 4 Notwithstanding items 2 and 3 above, the subject-matter of claim 2 is not new (cf. item 5, hereafter). The requisite unity of invention (Rule 13.1-13.3 PCT) therefore no longer exists inasmuch as a technical relationship involving one or more of the same or corresponding special technical features in the sense of Rule 13.2 PCT does not exist between the subject-matter of the groups of inventions I-VIII.

4.1 The application discloses the following groups of inventions I-VIII:

Group I (claims 2 (part), 3): a method in the fabrication of an organic thin film semiconducting device characterized in that the conductive material of the first layer is a metal.

Group II (claims 2 (part), 4): a method in the fabrication of an organic thin film semiconducting device characterized in that the semiconductor material of the first layer is selected among Si, Ge or GaAs.

Group III (claim 5): a method in the fabrication of an organic thin film semiconducting device characterized in that the second layer is deposited from a dispersant or a solution.

Group IV (claim 6): a method in the fabrication of an organic thin film semiconducting device characterized in that the second layer is deposited in a melt application process.

Group V (claim 7-10): a method in the fabrication of an organic thin film semiconducting device characterized in that the conducting polymer material of the second layer is selected.

Group VI (claim 11): a method in the fabrication of an organic thin film semiconducting device characterized in that the third layer is also deposited above a portion of the substrate not covered by the anode.

Group VII (claim 12-13): a method in the fabrication of an organic thin film semiconducting device characterized in that the organic semiconducting material of the third layer is selected.

Group VIII (claims 14-16): a method in the fabrication of an organic thin film semiconducting device characterized in that the metal of the fourth layer is selected.

- 4.2 The common concept in inventions I-VIII is a method in the fabrication of an organic thin film semiconducting device, the device comprising in this order a substrate, an anode, organic semiconducting material and cathode layers, in which device the anode comprises a second layer of a conductive polymer deposited on a first layer, the conductive polymer of the second layer having a higher work function than that of the material of the first layer. This combination in the anode improves the charge injection properties in the device.
- 4.3 However, this common concept is already known from D1 (cf. item 5, hereafter) and there is no corresponding technical relationship among the special technical features (cf. item 4.1 above) of inventions I-VIII.
- 5 The present application does not comply with Article 33(2) PCT because the subject-matter of claims 1 and 2, notwithstanding item 2 above, and as far as it can be understood (cf. item 3, above), is not new in view of the content of document D1 (cf. Figure 1 and associated text; page 5, last paragraph to page 7, second paragraph; pages 9-10; page 17) (cf. also PCT Guidelines III, 4.8).
- 6 Claims 2-16 do not contain any additional feature which, in combination with the features to any claim to which they refer, involve an inventive step (Article 33(3), Rule 65(1),(2) PCT).
- 7 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

A method in the fabrication of organic thin-film semiconducting devices

The present invention concerns a method in the fabrication of an electrode means in an organic thin film semiconductor device, wherein the semiconductor device particularly is a rectifier diode with a high rectification ratio or an organic thin-film transistor or a hybrid organic/inorganic thin-film transistor; and a method for the fabrication of an organic thin-film rectifier diode with high rectification ratio, wherein the rectifier diode comprises a first layer and a second layer provided on the first layer, such that the first and the second layer together forms the anode of the rectifier diode, a third layer of a semiconducting organic material provided over the anode, such that the third layer forms the active semiconductor material of the diode, and a fourth layer of metal provided patterned or unpatterned over the third layer, such that the fourth layer forms the cathode of the rectifier diode.

Particularly the invention concerns the modification of the injection properties of electrode means in organic thin-film semiconductor devices and the improvement of the rectification ratio of organic thin-film rectifier diodes.

In international published application WO98/53510 (Cambridge Display Technology, Ltd.) there is disclosed a method for patterning an organic light-emitting device having an organic light-emitting layer underlying an electrode layer. The device also comprises another unpatterned electrode layer which forms the anode of the device. This anode layer shall inject positive charge carriers in an active organic semiconducting material and is formed as a double layer of indium tin oxide (ITO) which is transparent and polyethylene dioxide thiophene doped with polystyrene sulphonic acid (PEDOT-PSS) which contacts the active material. Although ITO is the preferred contact material of the anode, alternative conductive materials can be used, including various doped metal oxides or metals such as gold or its alloys. The conductive polymer for injecting positive charge carriers may then be polyethylene dioxide thiophene doped with polystyrene sulphonate (PEDOT-PSS) or doped polyaniline or combinations thereof. It is also preferred that the work function shall be high and in any case the anode material should be transparent and translucent, at least over some of its area and thus substrate supporting the anode layer, in this case a glass sheet, must likewise be transparent. The use of transparent, translucent or at least

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of poly(*p*-phenylene vinylene) (MEH-CN-PPV) doped with a small amount of a derivative of polythiophene (POPT). The acceptor layer is contacted by an electrode and covered by a glass substrate. The acceptor layer is laminated together with a donor layer of POPT doped with a small amount of
5 MEH-CN-PPV which is spin-coated on either indium tin oxide (ITO) substrates or glass coated with poly(ethylene dioxy thiophene) doped with polystyrene sulphonic acid (PEDOT-PSS). To ensure a low contact resistance a thin layer of gold was thermally evaporated on the glass substrate before the PEDOT material was spin-coated thereon. Since Granström & al.
10 describe a photovoltaic diode, it is evident that they are not concerned with obtaining a high rectification ratio such as will be desirable in switching diodes, nor is a difference in the work function values of the cathode and the anode an issue, although the materials envisaged for the anode, ITO, PEDOT and gold all have a high work function value, ranging from 4.8 for ITO to
15 well above 5 eV for PEDOT and gold, the work function values of the latter two being almost similar.

However, it has been found that particularly noble metals such as gold and platinum cause in a poor quality of a conducting polymer thin film deposited thereupon and very often the polymer film presents pin holes which are not
20 acceptable when the films are arranged in a sandwiched geometry. Moreover gold is a costly material, but apparently Granström & al. have selected gold because of its transparency and high work function value matching that of PEDOT-PSS.

In switching semiconductor devices with diode structures a high rectification
25 ratio at of the latter will be desirable and it is also desired that the contact surface between an electrode and a semiconducting polymer should provide efficient charge injection, but this latter feature is not of concern for collector electrodes, that are the anodes, in a photovoltaic device based on organic semiconducting materials.

30 It is known that the contact surface between a conducting and a semiconducting polymer has superior properties with respect to injection of charge. For example a conducting polymer based on poly(3,4-ethylenedioxythiophene) (PEDOT) possesses a very high work function which makes it suitable as anode in semiconductor components
35 based on organic semiconductors, but the high resistivity of PEDOT limits

the performance of components because of a very high series resistance. This is particularly unfortunate when the electrodes are patterned with line widths of the order of 1 μm . However, it is believed that such components shall be crucial to realizing high density memory cells for use in memory modules based on polymer as the memory material, provided that it will be possible to achieve the desired high data read-out speed. This shall, however depend on the possibility of highly conducting electrodes for the memory cells which can be manufactured with microfabrication methods.

The object of the present invention is therefore to provide methods for the fabrication of electrode means for use in organic semiconductor devices and such that the electrode combines superior charge injection properties with a high conductivity. Furthermore it is an object of the invention to provide a method which permits the fabrication of an electrode means of this kind with patterned line widths in the order of 1 μm . Finally it is also an object of the present invention to provide a method for fabricating an organic thin-film diodes with high rectification ratio, or electrode means for use in organic thin-film transistors.

The above-mentioned objects and advantages are achieved with a first method according to the invention which is characterized by forming a first layer of a base metal or an inorganic semiconducting material or as a combination of a base metal and an inorganic semiconducting material, depositing a second layer of a conducting polymer on the first layer, said conducting polymer being selected among polymer with a work function equal to or greater than the work function of the first layer, such that the actual work function of the electrode means in any case becomes equal to the work function of the selected conducting polymer, and providing the electrode means in the organic semiconductor device such that the second layer contacts at least a portion of an active semiconductor material in the semiconducting device; and with a second method according to the invention which is characterized by depositing the first layer in the form of a base metal or an inorganic semiconductor or a combination of a base metal and an inorganic semiconductor on an insulating substrate, said first layer being deposited patterned or unpatterned such that at least a portion of the substrate is covered thereby, and depositing the second layer in the form of a conducting polymer over the first layer such that the second layer wholly or partly covers the first layer, said conducting polymer being selected as a

conducting polymer with the work function equal to or greater than the work function of the first layer, whereby the work function of the anode in any case becomes equal to the work function of the conducting polymer.

5 It is according to the invention advantageous when the metal of the first layer is selected among calcium, manganese, aluminium, nickel, copper or silver. It is also preferred that the inorganic semiconducting material of the first layer is selected among silicon, germanium or gallium arsenide.

10 In preferred embodiments of the method according to the invention the second layer can be deposited as a dispersion from a dispersent or as a dissolved material from solution or alternatively deposited in a melt-application process.

15 It is according to the invention advantageous selecting the conducting polymer in the second layer on a doped conjugated polymer and then preferably selecting the conjugated polymer among poly(3,4-dioxyethylene thiophene) (PEDOT), a copolymer which includes the monomer 3,4-dioxyethylene thiophene; substituted poly(thiophenes), substituted poly(pyrroles), substituted poly(anilines) or copolymers thereof, whereas the dopant for the conjugated polymer preferably is poly(4-styrene sulphonate) (PSS).

20 In a preferred embodiment of the method according to the invention the doped conjugated polymer is selected as poly(3,4-ethylenedioxythiophene) (PEDOT) doped with poly(4-styrene sulphonate) (PSS).

25 In an embodiment wherein only a portion of the substrate is covered by the anode, the third layer may additionally be deposited over at least a part of the portion of the substrate which is not covered by the anode.

30 It is according to the invention advantageous selecting the semiconducting organic material in the third layer among conjugated polymers, or crystalline, polycrystalline, microcrystalline and amorphous organic compounds, and in case the conjugated polymer is selected, it is preferred that this is selected among poly(2-methoxy, 5-(2'-ethylhexyloxy)-1,4-phenylene vinylene) (MEH-PPV) or poly(3-hexylthiophene) (P3HT).

Finally it is according to the invention advantageous selecting the metal of the fourth layer among metals which have a lower work function than that of

the anode and then particularly selecting the metal of the fourth layer as the same as the metal selected for the first layer, but aluminium could in any case particularly be selected as the metal of the fourth layer.

5 The invention shall now be described in more detail with reference to the accompanying drawing figures as well as to examples of polymer-based diodes with high rectification ratio manufactured according to the method of the present invention.

Fig. 1a shows an example of the structure of a conducting polymer, viz. PEDOT-PSS.

10 fig. 1b an example of the structure of a conjugated polymer belonging to the class of polythiophenes, viz. P3HT,

fig. 1c an example of the structure of a conjugated polymer belonging to the class of polyphenylene vinylenes, viz. MEH-PPV,

15 fig. 2a a plan view of a first embodiment of a diode made according to the method of the present invention,

fig. 2b a plan view of another embodiment of a diode made according the method of the present invention,

fig. 2c a cross section along the line A-A through the diode in fig. 2b,

20 fig. 3a the current/voltage characteristics of a diode according to prior art manufactured according to two different processing protocols,

fig. 3b the current /voltage characteristics of a diode made by the method according to the present invention, and of a diode made according to prior art,

25 fig. 3c the current/voltage characteristics of a diode made by the method according to the present invention, and of a diode made according to prior art,

fig. 3d the current/voltage characteristics of a diode made by the method of the present invention, and of a diode made according to prior art,

30 fig. 3e the current/voltage characteristics of a diode made by the method according to the present invention, and of a diode made according to prior art,

fig. 3f the rectification ratio of a standard diode made by the method according to the present invention,

fig. 4 a semilog plot of the current/voltage characteristics of a prior art diode and a diode according to the present invention, with insert showing the rectification ratio as a function of the voltage for the diode according to the present invention,

fig. 5 the forward current density of a $100 \mu\text{m}^2$ diode according to the present invention scaled with the forward current density of the inventive diode in fig. 4, with insert showing a semilog plot of the current/voltage characteristics of the $100 \mu\text{m}^2$ diode, and

fig. 6 the forward current density of a $1 \mu\text{m}^2$ diode according to the present invention scaled with the forward current density of the inventive diode in fig. 2, with insert showing a linear plot of the current/voltage characteristics of the $1 \mu\text{m}^2$ diode.

The present invention can be used to realize electrode means for organic semiconductor components in thin-film electronics. In the anode a conducting polymer is used in the form of a conjugated polymer to which has been added a suitable dopant. Fig. 1 shows a structure of such a conducting polymer where the conjugated polymer is poly(3,4-ethylenedioxythiophene) (PEDOT) doped with poly(4-styrenesulphonate) (PSS). This type of conducting polymer shall in the following be termed as PEDOT-PSS. Fig 1b shows the structure of a semiconducting conjugated polymer belonging to the class of polythiophenes, namely poly(3-hexylthiophene) (P3HT) and fig. 1c shows the structure of another semiconducting conjugated polymer, belonging to the class of polyphenylenevinylenes, namely poly(2-methoxy,5-(2'-ethylhexyloxy)-1,4-phenylenevinylene) (MEH-PPV). The use of these materials is well-known within organic semiconductor technology.

Fig. 2a shows a first embodiment of a diode in thin-film electronics made by the method according to the present invention. On a substrate 1 which is made by an electrically insulating material, e.g. glass or silicon where the surface is selectively oxidised to form silicon dioxide, there is patterned an electronic conductor with good conductivity, for example a metal in the form of thin stripes 2 which constitute a first layer 2 in the diode. The metal may

be chosen among calcium, manganese, aluminium, nickel, copper or silver. Since the layer 2 constitutes a part of the anode in the diode, it might seem reasonable to select a metal with high work function value, for example Au or Pt as known in the prior art. However, these noble metals are more or less chemically inactive and, at least as far as gold is concerned, also have a tendency to migrate into adjacent layers. Also gold should be avoided for reasons set out in the introduction. Therefore, according to the invention a metal with low work function shall be selected, for example copper, aluminium or silver which provide good adhesion to the overlying second layer 3 which is made with a conducting polymer with high work function value. According to a preferred embodiment of the invention the second layer 3 employs a conducting polymer in the form of PEDOT doped with PSS. In fig. 2a this second layer 3 of PEDOT-PSS is patterned conformally with the first layer 2, and the combination metal/PEDOT-PSS now constitutes the anode 2, 3 of the diode. Above the anode 2, 3 there is then provided a third layer 4 of a semiconducting polymer. According to a preferred embodiment of the invention the third layer is made of a semiconducting polymer, such as for instance preferably poly(2-methoxy,5-(2'-ethylhexyloxy)-1,4-phenylene vinylene) (MEH-PPV). Other semiconducting polymers may also be used, e.g. poly(3-hexylthiophene) (P3HT) may be relevant. Over the third layer 4 of semiconducting material the cathode 5 is now applied as a stripe electrode made from a metal with a suitably low work function value. This metal may e.g. be aluminium, but is not limited thereto and may in principle be made from other materials with comparable electronic properties, e.g. indium tin oxide (ITO). The diode in fig. 2a now appears as a sandwich structure with the anode made from several patterned stripe electrodes and shall be representative for embodiments where the active area, i.e. the semiconductor layer 4, typically is of the size in the order of 1 -100 μm^2 .

Fig. 2b shows a diode structure where the metal layer in the anode 2, 3 is deposited unpatterned, e.g. on one half of the substrate 1. The conducting material 3 which again preferably may be PEDOT-PSS, is deposited mainly over the whole metal layer 2 and the anode 2, 3 is now realized and is well suited for use in high-power diodes. Again, the active material 4 in the form of a semiconducting material is deposited over the anode 2, 3, with the cathode 5 on top, made from e.g. aluminium, deposited as two parallel wide stripes and forming the fourth layer in the diode structure. Fig. 2c shows a cross section through the diode of fig. 2b cut along the line A-A in the

longitudinal direction through a cathode stripe 5. Typically the embodiment of the diode as shown in figs. 2b and 2c may represent a diode with an active area (i.e. the active semiconductor area 3) of the order of $6-10 \text{ mm}^2$.

5 In each case the embodiments of fig. 2 emerge as organic thin-film diodes in a sandwich construction.

Fig. 3a shows current/voltage characteristics of a prior art device in planar geometry made with PEDOT between copper electrodes, in that the curve with filled circles shows the characteristics of PEDOT spin-coated at 4000 rpm and the curve with open circles the characteristics of PEDOT spin-coated at 1000 rpm. The distance between the copper electrodes is approximately 1 mm and the characteristic is linear, which is typical of an ohmic resistance.

Fig. 3b shows the current/voltage characteristic expressed respectively through the forward current in the conducting direction and backward current in the blocking direction of a diode according to prior art (solid lines) and of a diode made according to the method of the present invention (lines with circles/dots). The known diode is made with P3HT as the semiconducting material, spin-coated at 600 rpm from a 5 mg/ml solution and arranged between a copper anode and an aluminium cathode, respectively. The current in the forward direction is shown by the upper solid line and the current in the backward direction by the lower solid line. The diode made by the method according to the present invention has an anode 2, 3 made from a double layer of copper and PEDOT-PSS as the conducting polymer, spin-coated at 3000 rpm. The active semiconducting material P3HT is spin-coated at 600 rpm from a 5 mg/ml solution, and the cathode is made from aluminium. In this case the characteristic has been determined through two measurement series, and as can be seen from fig. 3b the results are virtually identical. The respective measurement series are discerned through curves with open or closed circles, respectively. The two upper, almost coinciding curves exhibit the current in the forward direction, while the lower curves exhibit the current in the backward direction. The difference compared to the diode made by conventional means is obvious.

Correspondingly fig. 3c shows the current/voltage characteristics of a diode according to prior art and a diode made according to the present invention. The diode according to known art employs MEH-PPV spin-coated at 800 rpm

from a 5 mg/ml solution as the semiconductor material, arranged in sandwich between a copper anode and an aluminium cathode, respectively.

Current/voltage characteristics are here represented by a curve with filled circles. The diode made by the method according to the present invention
5 employs the same organic semiconductor material deposited under similar conditions, but again the anode is a double layer of copper with PEDOT-PSS spin-coated at 4000 rpm, and the cathode is made from aluminium. The characteristic in this case is shown as a curve with open circles and the difference between the characteristics of the known component and the
10 component made by the method according to the present invention is again obvious.

Fig. 3d shows in the same way as in fig. 3c the current/voltage characteristics of the same components, in that the conducting material and the active organic semiconducting material are deposited under exactly the same
15 conditions respectively, but in both cases the anode is now made with aluminium.

Fig. 3e shows the current/voltage characteristics of a diode according to prior art and a diode made by the method according to the invention. The known diode employs active material consisting of MEH-PPV spin-coated at
20 600 rpm from a 5 mg/ml solution and arranged in sandwich between a nickel anode and an aluminium cathode. The characteristic is in this case shown by a curve with filled circles. The diode made by the method according to the present invention employs an anode made by a double layer of nickel and PEDOT-PSS spin-coated at 4000 rpm, while the active material is MEH-PPV
25 spin-coated at 600 rpm from a 5 mg/ml solution, and the cathode is again aluminium. The characteristic is in this case shown by a curve with open circles.

Finally, fig. 3f shows the rectification ratio for a standard diode made by the method according to the present invention and with an anode in the form of a
30 double layer of Cu/PEDOT-PSS, the active organic semiconductor in the form of MEH-PPV, and with aluminium as the cathode. As can be seen, at voltages of 3 volt and above a rectification ratio as high as $10^6 - 10^7$ is achieved.

According to the present invention anodes formed as double layers with
35 metal, alternatively a semiconductor, or a semiconductor and a metal in

combination, under a layer of a conducting polymer in the form of PEDOT-PSS shall improve the conductivity. The metal and the semiconductor in the anode may be Cu or Al which both possess a low work function, but in combination with PEDOT the anode appears with essentially the high work function of PEDOT. At the same time the combination of metal and PEDOT improves the conductivity of the anode. The PEDOT-PSS layer modifies the injection properties of the anode metal which has a low work function value, providing a problem-free hole injection. If the anode were made from metal only, the current flow would be limited by the contact, but the use of PEDOT-PSS ensures that the current flow now shall be bulk-limited. By using a metal/PEDOT-PSS-anode it is, as shown in fig. 3f, possible to make diodes with a rectification ratio of up to seven orders of magnitude. A major advantage which is achieved by employing an anode of metal and a conducting polymer, is the possibility of being able to pattern the anode. The use of metal under PEDOT yields higher conductivity along the electrodes compared to the conducting polymer itself. Even with patterned electrodes with line widths of the order of $1\mu\text{m}$, high current density can be achieved in combination with superior charge injection properties. This can be used to realize memory cells in polymer memories with high data storage density, and it becomes possible to achieve high read-out speeds because of the highly conducting electrodes. At the same time the memory cells may be realized with line widths in the order of $1\mu\text{m}$ by suitable patterning of the metal/polymer layer. In this connection it should be remarked that the contact between any metal in the anode and a highly doped conducting polymer shall be ohmic.

Below follows examples of diodes made by the method according to the present invention and the associated current/voltage characteristics that have been achieved, and associated figures.

Example

A large effort has been undertaken towards fabrication of electronic devices using polymers. Most of these are directed towards field-effect transistors and diodes, in imitation of silicon electronics. Among the diodes, both light emitting diodes and light detecting diodes constitute the major fraction of the studies; in both of these a transparent electrode is suitable. However, a high rectification organic diode is quite important for a broad spectrum of electronic applications. In order to fabricate diodes based on semiconducting

polymers with high rectification, one needs materials that allow efficient charge injection through the polymer under forward bias, and much less so under reverse bias. Normally this is achieved using materials that match in energy position, or make low potential barriers, to the HOMO (Highest Occupied Molecular Orbital) and LUMO (Lowest Unoccupied Molecular Orbital) levels of the polymer. In the reverse bias both barriers for electrons and holes must be high enough to keep the current low, having thus as a result a high rectification ratio. But it is not just the energy levels that matter. The interface properties and the quality of the polymer film formed onto a given metal can define the diode properties; often polymer film spin-coated onto inert materials such as gold presents pin holes that are not acceptable if one needs to evaporate an upper electrode on top of the polymer film in a sandwich geometry. The conducting/semiconducting polymer interface tends to have good adhesion. The oxidized conducting polymer poly(3,4-ethylenedioxythiophene) doped with poly(4-styrene sulphonate) (PEDOT-PSS) was found to have the high work function value 5.2 eV which allows efficient hole injection in LEDs or collectors in photodiodes. However, the higher resistance of PEDOT-PSS compared with ordinary metals may compromise the diode performance in thin patterned lines, due to voltage drop under high currents. To handle this problem, a metal layer under the polymer is used. Any metal can be used as the underlying layer as it is not necessary to match the work function of the metal (ϕ_m) with the work function of PEDOT (ϕ_{PEDOT}). Since noble metals like gold and platinum which is commonly used in organic light-emitting diodes, are known to comport detrimental effects when used in conjunction with PEDOT, the preferred metals will be base metals with high conductivity. – The expression “base metals” as used herein, as opposed to noble metals, should be understood as metals with electrochemical potential less than 1 volt. – Diodes made with several metals (Al (4.2 eV), Ag (4.3 eV), Cu (4.5 eV)) were tested. In all cases the current flow of holes which was contact-limited, changed to bulk-limited when a PEDOT-PSS layer was used between the anode metal and the semiconducting polymer MBH-PPV (poly(2-methoxy, 5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene)). In order to study the electrical properties of diodes with different active areas copper was chosen as the underlying layer, particularly due to its good stability and etching properties. The Cu/PEDOT-PSS interface was demonstrated to be ohmic with a contact resistance $r_c \approx 7 \Omega/\square$. The ohmic behaviour of Cu/PEDOT-PSS interface is

an important asset for its use as an electrode in diodes. The contact resistance of Cu/PEDOT-PSS interface was measured using planar geometry to provide a copper surface similar to that used for the diodes.

The diodes were constructed in sandwich geometry using Cu/PEDOT-PSS as the anode and Al as the cathode ($\phi = 4.2$ eV). They were mounted onto a glass or Si with $2\text{ }\mu\text{m}$ thick oxide substrate, as shown in figs. 2a-c. Figure 2b shows the geometry for the ordinary diodes, usually with $6\text{-}10\text{ mm}^2$ active area. For these diodes the copper layer was deposited by evaporation to a preferred thickness of 200 nm onto one half of the substrate. The PEDOT-PSS (Bayer AG, Germany) layer with a thickness of 80 nm , was deposited by spin-coating from a solution of water with 30% isopropanol, and filtered using a $1\text{ }\mu\text{m}$ pore glass filter. The PEDOT-PSS was patterned conformally onto the copper and then annealed for 5 min. in 120° C. It was noticed that the PEDOT-PSS solution reacts with copper oxide, etching the surface of the Cu film, which eases the formation of the contact. The semiconducting polymer layer was deposited by spin-coating using a MEH-PPV polymer dissolved into chloroform at the concentration of 5 mg/ml , to a thickness of 190 nm . The second electrode Al was vacuum evaporated through a shadow mask defining the active area. For the diodes with $1\text{ }\mu\text{m}^2$ and $10\text{ }\mu\text{m}^2$ of active area the construction followed the patterning steps common in the Si technology. The processing includes patterning of Cu layer (200 nm thick) with PEDOT-PSS (80 nm thick) on top in $500\text{ }\mu\text{m}$ long stripes with width of $1\text{ }\mu\text{m}$ and $10\text{ }\mu\text{m}$, followed by the annealing treatment. This patterned substrate was covered with MEH-PPV by spin-coating and Al was sputtered on top and patterned in stripes similar to Cu in order to make intersections of $1\text{ }\mu\text{m}^2$ and $100\text{ }\mu\text{m}^2$. The geometry of a diode of this kind is presented in fig. 2b.

The I-V characteristics of two similar diodes made using MEH-PPV polymer is presented in fig. 4, which shows a semilog plot of the current/voltage characteristics of a MEH-PPV-based diode using a copper anode (open circles) and a similar MEH-PPV-based diode using a Cu/PEDOT-PSS anode (solid circles). The insert graph here shows a semilog plot of the rectification ratio versus the voltage for the diode with the Cu/PEDOT-PSS anode. The measurements were performed using a Hewlett Packard 4156A precision semiconductor parameter analyser in dark environment. It is possible to notice the difference in the shape of the current-voltage dependence due to

the inclusion of the PEDOT-PSS layer. Due to higher value of the work function of PEDOT-PSS (5.2 eV) compared to Cu (4.5 eV), the energy barrier for hole injection from PEDOT-PSS to the MEH-PPV is $\phi \approx 0.1$ eV. This is much smaller than that from Cu to MEH-PPV which is $\phi \approx 0.8$ eV, as the current limitation in these two situations are different. Copper presents a contact-limited current regime; in this low injection regime the current densities are small and space charge effects can be neglected. With the inclusion of a thin layer of PEDOT-PSS it will be possible to make a transition to a bulk-limited current regime where the forward current is mostly due to the positive carriers coming from the Cu/PEDOT-PSS electrode. The Cu/PEDOT-PSS/MEH-PPV/Al diodes presented a $J(V)$ function with three limiting regions, J being the current density. From 0 to 1 volt the current is at the noise level of the equipment; little charge flow occurs. This condition is due to the difference in the work function values of the electrodes (PEDOT-PSS and Al ≈ 1 eV) which creates an inherent potential in the polymer layer that opposes hole injection. One first has to apply this voltage in order to inject charge. Between 1 and 2 volts the current has an exponential behaviour, and increases by five orders of magnitude. This dramatic increase is a property of the interface PEDOT-PSS/MEH-PPV with its low energy barrier. Beyond 2 volts the current becomes dependent on the transport properties of the MEH-PPV layer. The insert graph in fig. 4 shows the rectification ratio value of this diode as a function of voltage, the rectification ratio being taken by dividing the forward by the reverse current. At 3 volts it already shows a rectification ratio of six orders of magnitude, increasing to seven between 4 and 8 volts. Beyond 8 volts the injection of holes from Al to MEH-PPV increases the reverse current decreasing the rectification ratio value.

Fig. 5 shows the forward current density of a $100 \mu\text{m}^2$ diode according to the invention and with Cu/PEDOT-PSS/MEH-PPV/Al structure (solid triangles) scaled with the forward current density (solid circles) of the diode according to the invention as shown in fig. 4, while the insert graph shows a semilog plot of the current/voltage characteristic of the $100 \mu\text{m}^2$ diode.

The Cu/PEDOT-PSS/MEH-PPV/Al diodes with $100 \mu\text{m}^2$ of active area presented similar shape of the forward current/voltage characteristic, as can be seen in the insert graph in fig 5. In order to compare the I-V characteristics of both diodes, the current density are plotted in fig. 5 both for

the diode in fig. 4 (8 mm^2) and for the diode with $100 \mu\text{m}^2$. The shift in the absolute value of the current can be understood due to the thickness difference between the diodes. The scaling is quite consistent.

5 Fig. 6 shows the forward current density of a $1 \mu\text{m}^2$ diode according to the present invention and with a Cu/PEDOT-PSS/MEH-PPV/Al structure (open squares) scaled with the forward current density (solid circles) of the diode according to the invention in fig. 4, while the insert graph shows a linear plot of the current/voltage characteristic of the $1 \mu\text{m}^2$ diode.

10 However, for a diode of this size the current level is quite low, around the noise level as can be seen in the insert graph in fig. 5. The I-V characteristics for the current density of both the diode with $1 \mu\text{m}^2$ active area and the one of 8 mm^2 active area are plotted. The function $J(V)$ for the smaller diode is plotted up to twenty volts. It will be seen that its behaviour and shape do not scale very well with the larger diode. In these small diodes, the area
15 extension is only ten times the thickness of the layers, and fringe fields are expected to start becoming important; even more important may be the existing irregularities causing any geometrical estimates to err.

The electrical transport properties of conjugated polymers and polymer/metals junctions has been studied for quite some time. The first
20 attempt in modelling the PPV-based diodes was based on the Fowler-Nordheim model describing the tunnelling process in the diode. It was possible to obtain the approximate values for barrier heights and for the polymer energy levels. A number of models has since then been presented taking in account more parameters for detailing the interface properties. It
25 is proposed that when the current is contact-limited it can be determined by the image force, the effect of Coulomb trapping of carriers at the interface. This trapping results in an increase of the energy barrier height, decreasing the injection flow. It was concluded that the presence of an insulating material free of traps could increase the charge injection. In the case of PEDOT-PSS
30 it was shown that during the deposition of this material by spin-coating a segregation of PEDOT and PSS takes place. PSS is an insulating material and it was found to form a thin layer all over the PEDOT surface film. This thin layer cannot trap charges from the electrode which may account for the improvement in the carrier injection from PEDOT. The bulk-limited current
35 of MEH-PPV has been studied and reported by several research groups. It

- was found that at high fields MEH-PPV presents a spatial charge limitation of the current, and also that mobility is dependent on the applied electric field. In the present case the behaviour is similar, as the current does not depend on V^2 precisely because of the field-dependent mobility. This was proposed in a recent study by Malliaras & al., PRB, Vol. 58, R13411 (1998). The use of a model developed by P. N Murgatroyd (J.Phys. D., Vol. 3, 151 (1970)) combines spatial charge limitation dependence with the non-constant mobility in the same equation. From these models one can evaluate the data obtained herein by plotting the high field current in the function format JL^3 versus $(VL)^{0.5}$, where J is the current density, L the polymer thickness and V the applied voltage minus the built-in voltage of the diodes. For the present invention this enabled a data fit and gave similar values for the polymer parameters μ_0 and E_0 , i.e. the zero field mobility and the characteristic field respectively.
- In summary, the present invention provides a high rectification ratio polymer diode using two low work function metals, where the anode was modified by the introduction of a conducting polymer layer, PEDOT doped with PSS. With this surface modification it was possible to progress from a low injection contact-limited current to a high injection bulk-limited current. The PEDOT/PSS segregation might add to the charge injection by avoiding Coulomb trapping at the interface due to the image force effects. The possibility of making these diodes patterned on micrometer scale has been shown. This offers the prospect of fabricating such diodes for microelectronics with active devices such as switching diodes and switching transistors, but also in electrically addressable high-density thin-film memories in e.g. a passive matrix.
- In addition electrode means as herein disclosed may also be used for the electrodes in organic thin-film transistors, for instance of the kind disclosed in the above-mentioned patent application EP 0 716 459 A2, for replacing conventional electrodes with gold or gold combined with another metal.

the work function of the anode in any case becomes equal to the work function of the conducting polymer.

3. A method according to claim 1 or claim 2,
characterized by selecting the metal of the first layer among calcium,
5 manganese, aluminum, nickel, copper or silver.
4. A method according to claim 1 or claim 2,
characterized by selecting the inorganic semiconducting material of the first
layer among silicon, germanium or gallium arsenide.
5. A method according to claim 1 or claim 2,
10 characterized by depositing the second layer as a dispersion from a
dispergent or as a dissolved material from a solution.
6. A method according to claim 1 or claim 2,
characterized by depositing the second layer in a melt application process.
7. A method according to claim 1 or claim 2,
15 characterized by selecting the conducting polymer in the second layer as a
doped conjugated polymer.
8. A method according to claim 7,
characterized by selecting the conjugated polymer among
poly(3,4-dioxyethylene thiophene) (PEDOT), a copolymer which includes the
20 monomer 3,4-dioxyethylene thiophene; substituted poly(thiophenes),
substituted poly(pyrroles), substituted poly(anilines) or copolymers thereof.
9. A method according to claim 7,
characterized by selecting the dopant for the conjugated polymer as
poly(4-styrene sulphonate) (PSS).
- 25 10. A method according to claims 7 and 8,
characterized by selecting as the doped conjugated polymer as
poly(3,4-ethylenedioxythiophene) (PEDOT) doped with poly(4-styrene
sulphonate) (PSS).
- 30 11. A method according to claim 2, wherein only a portion of the substrate
is covered by the anode,
characterized by the third layer additionally being deposited over at least a
part of the portion of the substrate which is not covered by the anode.

12. A method according to claim 2,
characterized by selecting the semiconducting organic material in the third
layer among conjugated polymers, or crystalline, polycrystalline,
microcrystalline and amorphous organic compounds.
- 5 13. A method according to claim 2,
characterized by selecting the conjugated polymer in the third layer among
poly(2-methoxy, 5-(2'-ethylhexyloxy)-1,4-phenylene vinylene) (MEH-PPV)
or poly(3-hexylthiophene) (P3HT).
- 10 14. A method according to claim 2,
characterized by selecting the metal of the fourth layer among metals which
have a lower work function than that of the anode.
- 15 15. A method according to claim 14,
characterized by selecting the metal of the fourth layer as the same as the
metal selected for the first layer.
16. A method according to claim 15,
characterized by selecting aluminum as the metal of the fourth layer.

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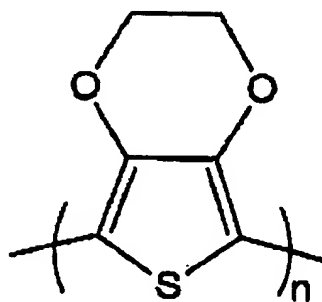


Fig. 1a

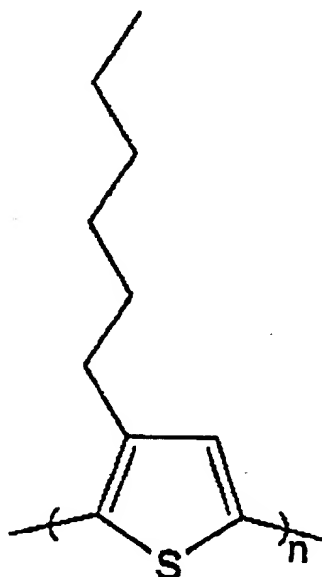


Fig. 1b

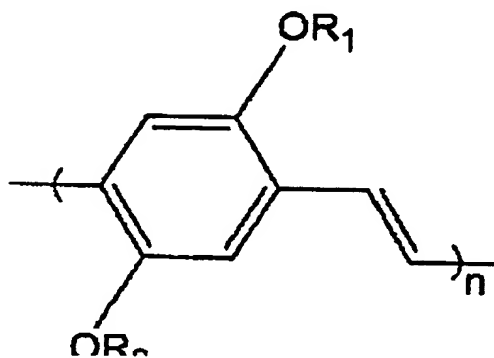
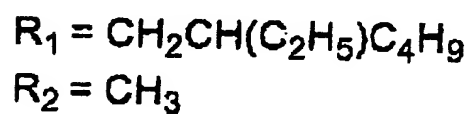


Fig. 1c

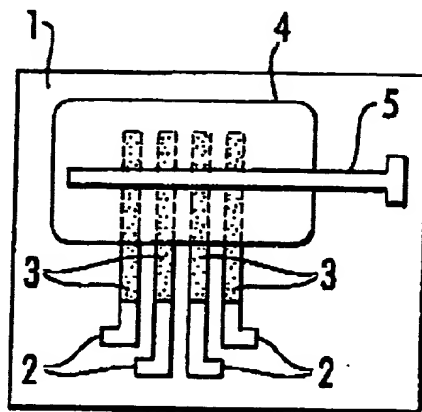


Fig. 2a

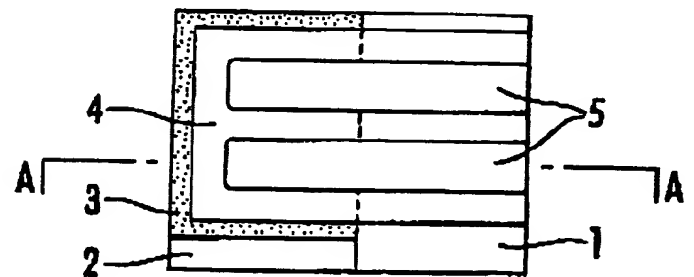


Fig. 2b

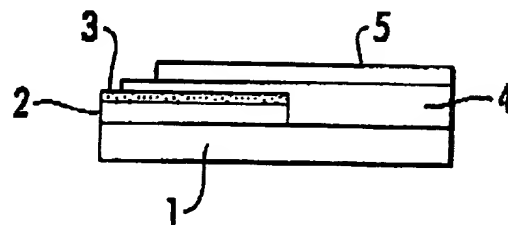


Fig. 2c

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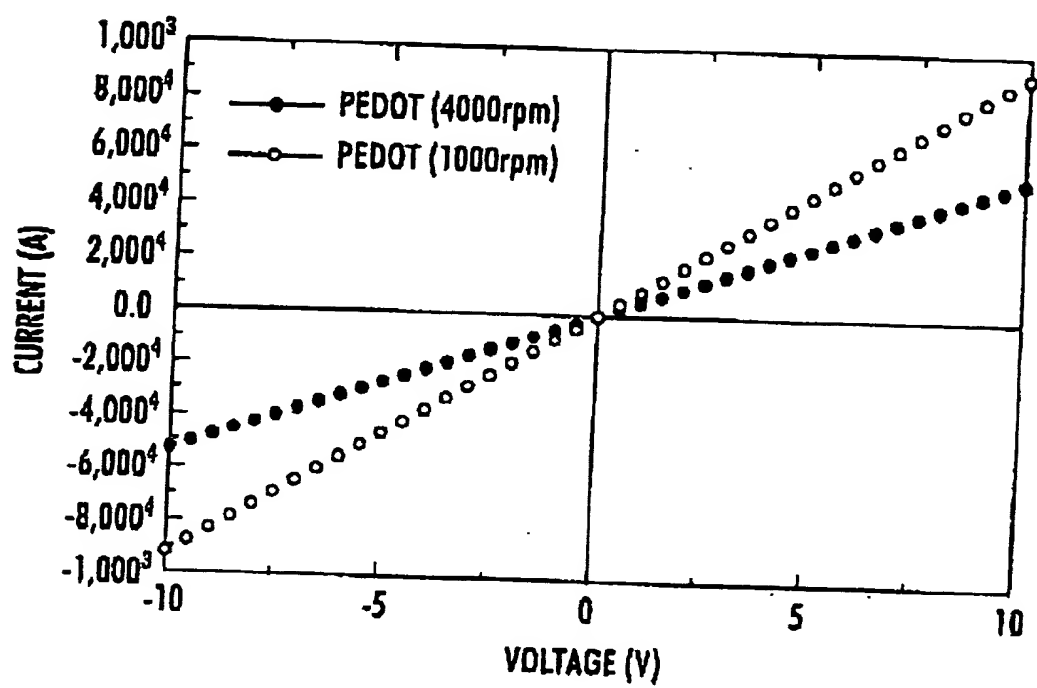


Fig.3a

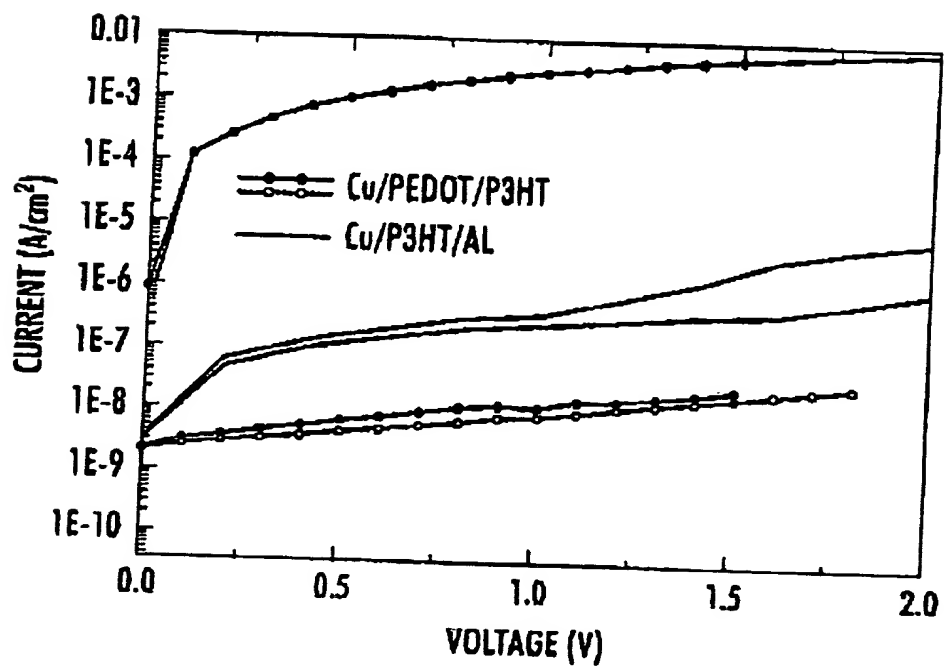


Fig.3b

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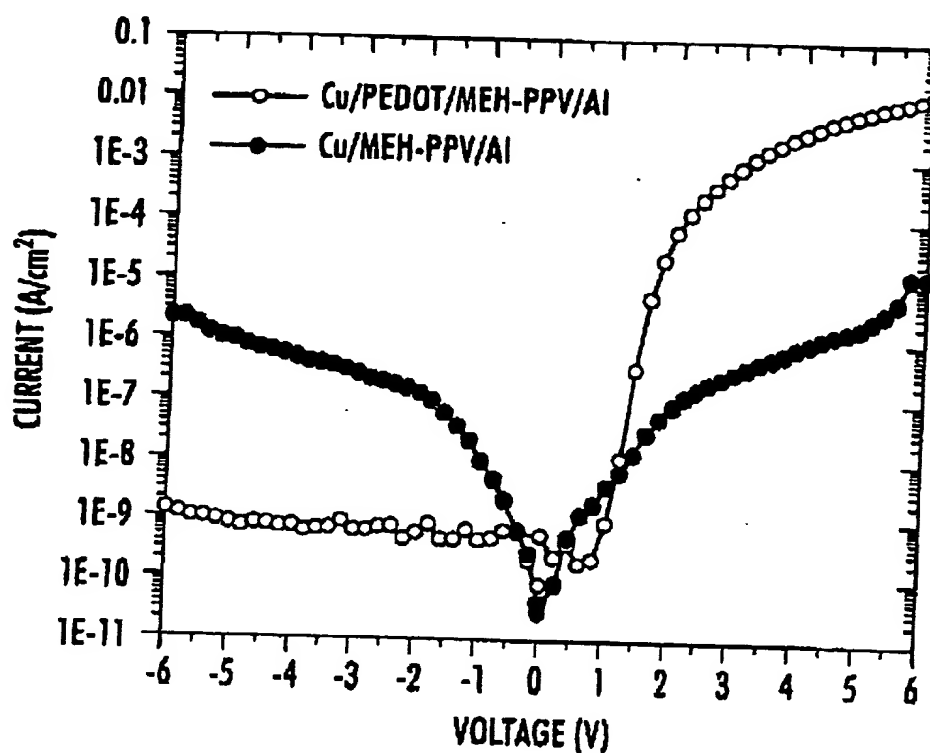


Fig.3c

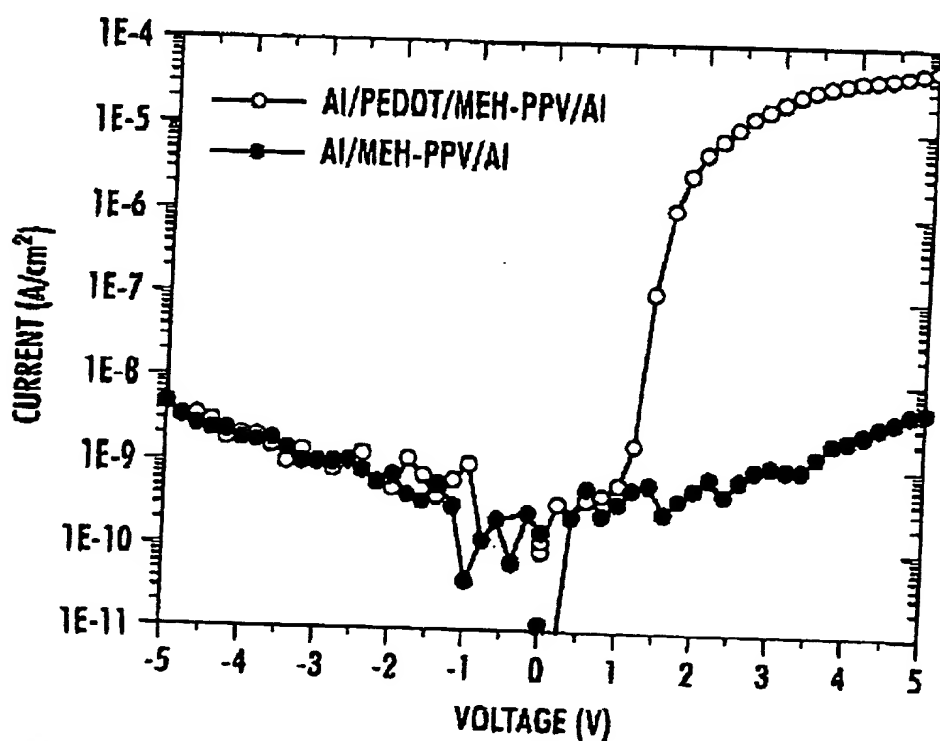


Fig.3d

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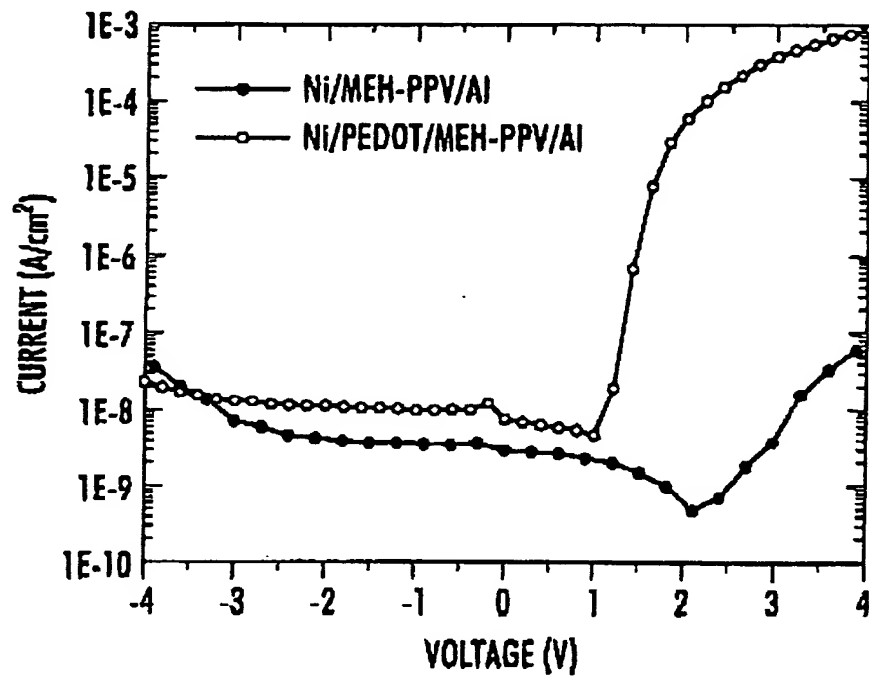


Fig.3e

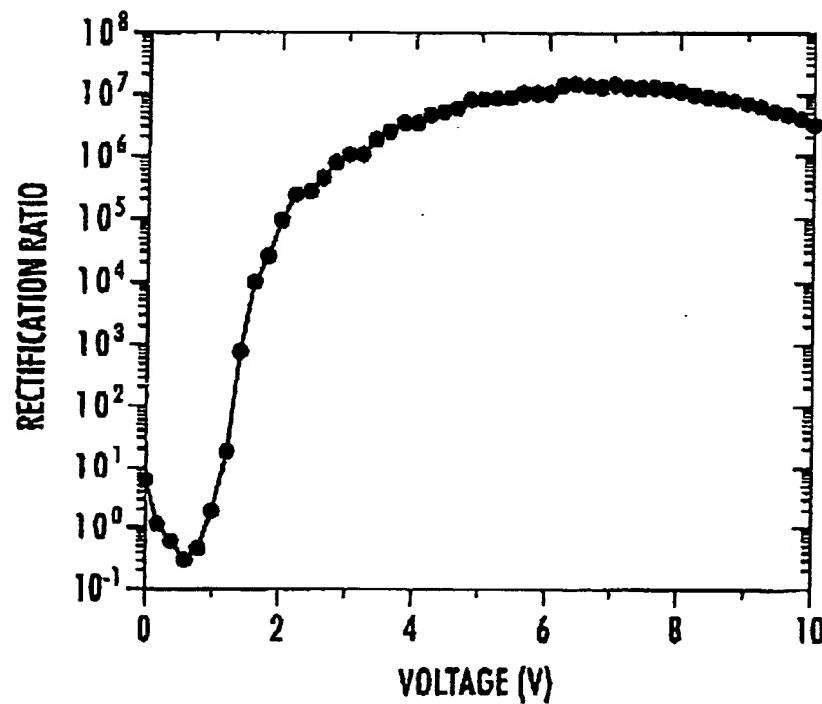
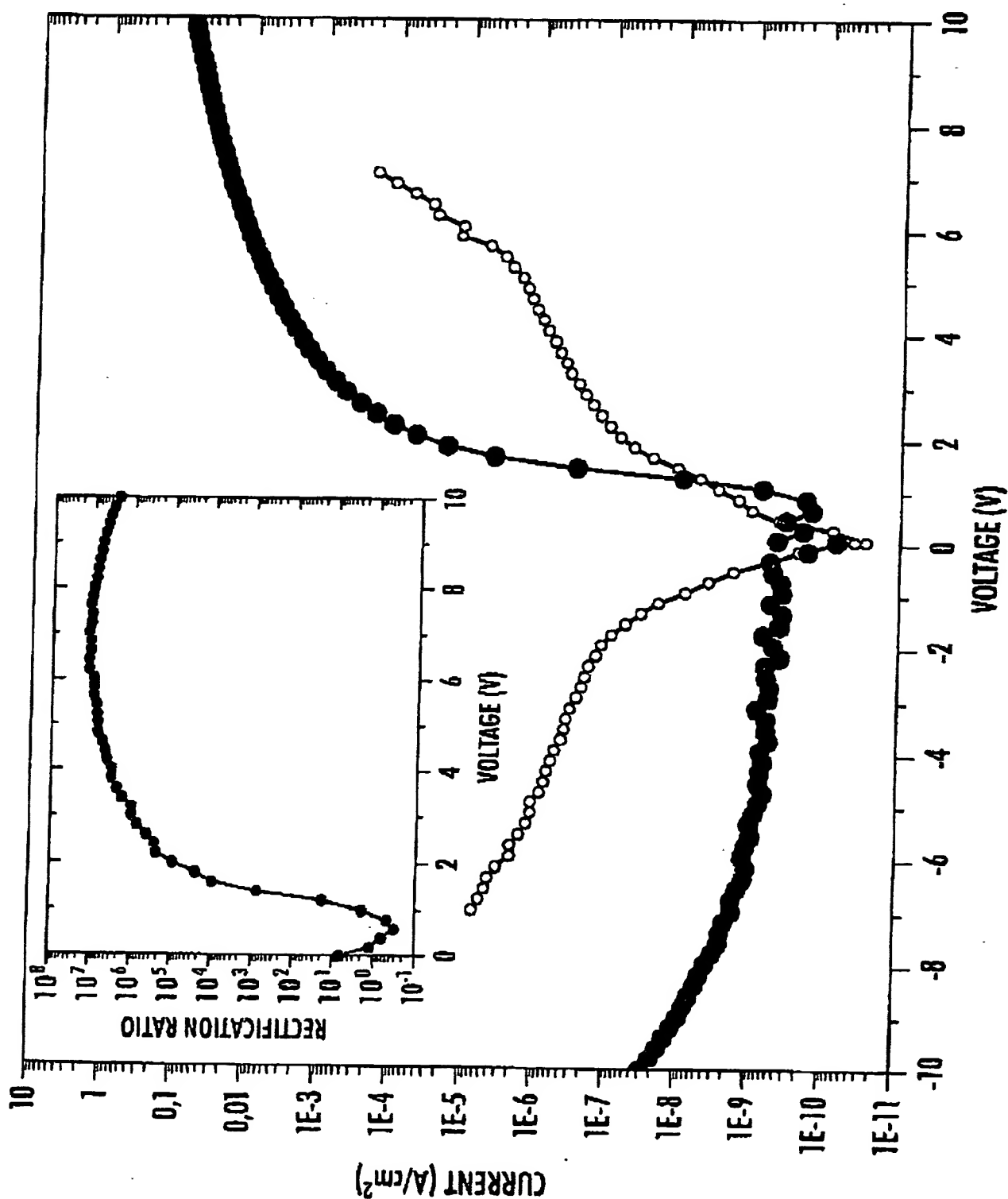


Fig.3f

Fig.4



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Fig.5

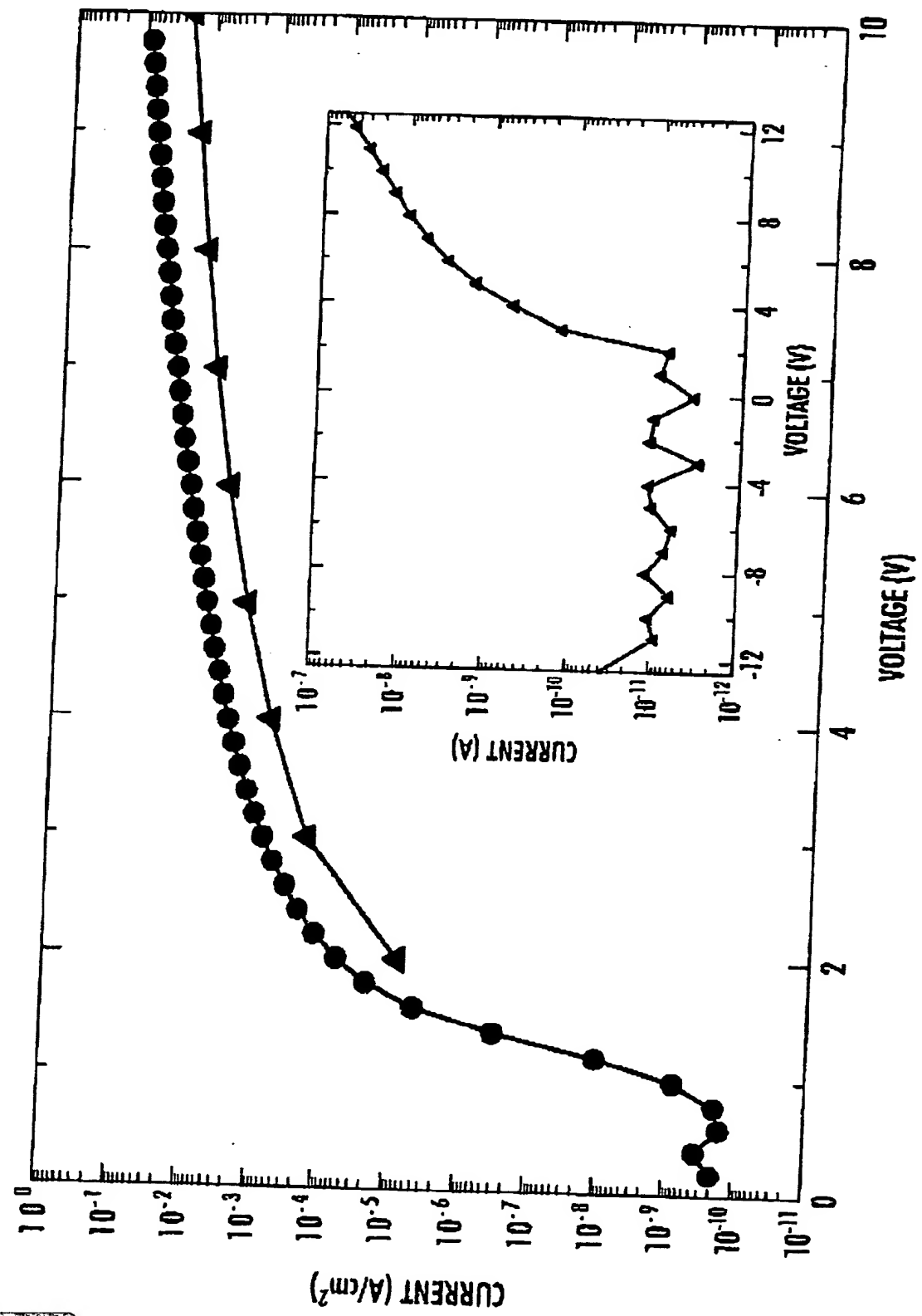
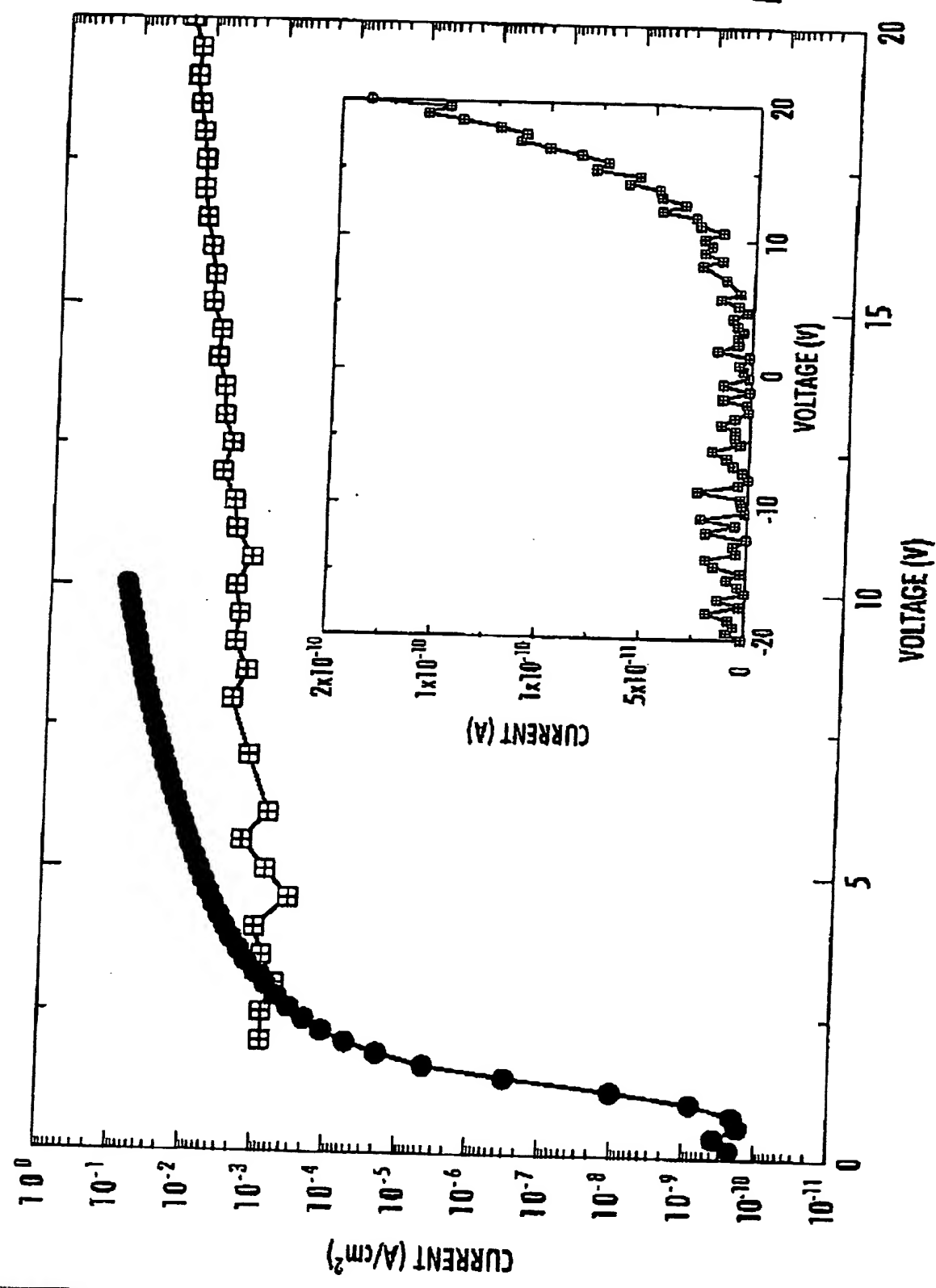


Fig.6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 00/00127

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01L 27/01, H01L 49/02, H01L 51/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9853510 A1 (CAMBRIDGE DISPLAY TECHNOLOGY LTD), 26 November 1998 (26.11.98), page 5 - page 11, figure 4, abstract	1,5,11,12, 16,17
A	--	2,3,4,6-10, 13-15
X	EP 0901176 A2 (CAMBRIDGE DISPLAY TECHNOLOGY LTD), 10 March 1999 (10.03.99), column 1, line 51 - column 4, line 22, figure 1, abstract	1,5,11,12, 16,17
A	--	2-4,6-10, 13-15

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents	"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document but published on or after the international filing date	"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

6 October 2000

Date of mailing of the international search report

09-10-2000

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 00/00127

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5726457 A (TSUYOSHI NAKANO ET AL), 10 March 1998 (10.03.98), column 3, line 28 - column 10, line 42, figure 3, abstract	1,2,5,11,12, 16,17
A	---	3-4,6-10, 13-15
A	EP 0716459 A2 (AT&T CORP.), 12 June 1996 (12.06.96), column 2, line 48 - column 4, line 45, figure 2, abstract	1-17
A	EP 0786820 A2 (MOTOROLA, INC), 30 July 1997 (30.07.97), column 2, line 6 - line 22, figure 2, abstract	1-17
A	EP 0852403 A1 (LUCENT TECHNOLOGIES INC.), 8 July 1998 (08.07.98), page 1, line 57 - page 2, line 27, figure 1, abstract	1-17

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/NO 00/00127

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
WO	9853510	A1	26/11/98	GB	9710344 D	00/00/00
EP	0901176	A2	10/03/99	GB	9718393 D	00/00/00
US	5726457	A	10/03/98	DE	69110922 D,T	07/12/95
				EP	0443861 A,B	28/08/91
				JP	2987865 B	06/12/99
				JP	3244630 A	31/10/91
				US	5317169 A	31/05/94
				JP	3273087 A	04/12/91
				JP	2998187 B	11/01/00
				JP	4145192 A	19/05/92
EP	0716459	A2	12/06/96	CA	2164357 A	10/06/96
				JP	8228034 A	03/09/96
				SG	33622 A	18/10/96
				US	5596208 A	21/01/97
EP	0786820	A2	30/07/97	JP	9232589 A	05/09/97
EP	0852403	A1	08/07/98	JP	10190001 A	21/07/98

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO00/00127**Box I** Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a):

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO00/00127

The invention relates to a method in fabrication of an organic thin-film semiconductor device. The object of the invention is to manufacture an electrode which combines superior charge injection properties with a high conductivity. It is also an object to provide a method which permits the manufacturing of electrodes which can be used in organic thin-film diodes. This is done by making a semiconductor device comprising an electrode arrangement with an anode in a two-layer arrangement on a substrate, including a polymer, a third organic layer on top of the anode and a fourth cathode layer.

The invention according to claim 1 lacks of novelty.

The subject matter of the claims 2-17 does not constitute a single invention concept, therefore, there is a lack of unity of the invention *à posteriori*.

The following grouping (I-VII) has been made:

I: (Claims 2 and 3) A method characterized by the conducting material of the first layer being a metal.

II: (Claim 4) A method characterized by selecting the semiconductor material of the first layer among silicon, germanium or gallium arsenid.

III: (Claim 5) A method characterized by depositing the second layer as a dispersion from a dispergent or as a dissolved material from a solution.

IV: (Claim 6) A method characterized by depositing the second layer in a melt application process.

V: (Claims 7-10) A method characterized by the selecting of the conjugated polymer.

VI: (Claims 11-12) A method characterized by the selecting of semiconducting organic material in the third layer.

VII: (Claim 13) A method characterized by the selection of metal of the fourth layer among metals.

Consequently, there exists no common special technical features within the meaning of PCT Rule 13.2, second sentence, between the inventions I-X and no technical relationship within the meaning of PCT Rule 13 between the different inventions can be seen.